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Abstract

REACTOR PHYSICS RESEARCH IN UNITED KINGDOM UNIVERSITIES

by

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The paper describes briefly the work being carried out and the results so far obtained in those British universities which are actively engaged in Reactor Physics research.

The validity of using a graphite exponential assembly for control rod measurements in place of a critical system has been in some respects confirmed at Imperial College (University of London). It appears that if control rod extrapolation lengths are measured for a single rod, two-group theory satisfactorily predicts the behaviour of two- and four-rod assemblies. At this college work on neutron slowing down is progressing, using a cadmium covered Li-6 glass scintillation counter. Pulsed neutron measurements of diffusion parameters are also being made. The new 100 K.W. London University Reactor "Consort" will enable the effects of temperature gradients on neutron diffusion to be studied.

At Queen Mary College (London University), measurements on uranium/water lattices using resonance and $1/v$ detectors have revealed a dependence of the measured buckling upon the type of detector used. Mean neutron lifetimes in the lattices and diffusion parameters in various hydrogenous systems have been measured, using pulsed sources. A 10 watt critical reactor, designed to study hydrogenous systems, is under construction. A novel high precision reactor

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oscillator has been developed at the college and used on Harwell reactors. Theoretical and experimental studies on the uses of stochastic reactor theory are also in hand, and a binary stochastic oscillator has been constructed.

The group at Manchester University is studying the use of pulsed source techniques for measuring diffusion parameters and absorption cross-sections, giving special care to harmonic analysis. Neutron spectra measurements are being made on a natural uranium light water exponential assembly and a large graphite stack. The group is also studying the kinetics of water moderated systems, using pulsed sources and steady state measurements on voided assemblies. The Manchester-Liverpool Joint Reactor will greatly assist this work.

At Southampton University a nuclear engineering laboratory was set up in 1961 within the Mechanical Engineering Department. The main research tool is a natural uranium/water sub-critical assembly, coupled to a 150 KV positive ion accelerator. The research group is particularly interested in the use of pulsed source techniques for measuring the buckling of an irregularly shaped core, by comparisons with a simple one.

In Scotland, reactor physics research is based on the Scottish Research Reactor Centre, at which the basic equipment is a 100 K.W. U.T.R.-100 research reactor. This is now operating. The present research programme includes the development of crystal spectrometers for neutron spectrum determination.



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TECHNICAL OBJECTIVES OF THE VULCAIN
REACTOR PROJECT

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For several years there has been much interest in the use of D_2O/H_2O moderators in pressurised water reactors, giving improved neutron economy, and hence lower fuel costs. A method of employing this principle, giving a varying degree of moderation, and hence reactivity, throughout core life was suggested in 1957 for the Vulcain reactor, and is being developed through a series of experiments as part of a joint research programme between Belgonucleaire (supported by the Belgian Government and Centre d'Etudes Nucleaire) and the United Kingdom Atomic Energy Authority.

In addition to the target of low fuel costs, a further objective is to attain low capital costs by developing a compact, integral type water reactor with inherent load following characteristics. This type of reactor would also be suitable for small land-based power stations. The programme includes engineering research into heat-exchanger design, integral circulating pumps, self pressurisation, water treatment and hydraulic shut-down devices. Core design and fuel element development is to be demonstrated in a power experiment in the BR 3 reactor at Mol. This, and experimental physics work, are described in other papers. The optimisation of small cores using a mixed D_2O/H_2O moderator leads to a compact highly rated

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design with low D₂O inventory. This is particularly desirable for a marine system and also minimises heavy water investment cost.

The inherent self regulating characteristics of the Vulcain core are exploited to the extent that it is possible to dispense with conventional control methods for all conditions except xenon poisoning. This is provided for by soluble poison techniques embodied in the primary coolant purification system, thus eliminating mechanical control rods. Positive-acting safety rods are provided which are completely withdrawn from the core during normal operation.



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Abstract

FACTORS CONTROLLING THE REACTION BETWEEN GRAPHITE
AND RADIOLYSED CARBON DIOXIDE

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The paper reviews information obtained from basic investigation carried out in rigs in materials testing reactors by the United Kingdom Atomic Energy Authority on the radiation induced reaction between carbon dioxide and graphite. C-14 tracer techniques have been particularly useful in this work and their development and application have therefore been especially selected for description.

The principal parameters governing the reaction have been found to be the gas density and the porous structure of the graphite. In particular the reaction rate depends on the volume of the pores accessible to the external atmosphere and the amount of radiation energy absorbed by gas in these pores. Temperature and pressure have little specific effect apart from controlling the gas density and therefore the energy absorbed. The reaction is described in terms of the formation of active species in the gas within the porous structure; these migrate to and react with a carbon surface. Activated carbon dioxide molecules and oxygen atoms have been postulated as two types of active species. It is possible that both are important under different conditions.

The effects of attack on the graphite structure after massive (up to 19%) weight losses are described in terms of opening up of the closed pore structure. It is suggested that two types of closed pore are involved -

- (1) macropores which are similar in character to the open pores, and which open up rapidly during the early stages of the oxidation, and
- (2) micropores which may be part of the crack structure and which open up in proportion to the carbon removed.

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Small quantities of additives to the carbon dioxide can have a disproportionate effect on the reaction rate, and limited inhibition was observed with carbon monoxide, hydrogen and water vapour. Methane has been shown to be even more effective. The effects have been attributed to interference with surface processes.



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THE ECONOMIC SEPARATION OF STABLE ISOTOPES
ON A COMMERCIAL SCALE

by

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The separation of isotopes of boron and carbon has been carried out for some time in the U.K. In 1953 work on the separation of boron-10 was started being at that time mainly concerned with the supply of highly enriched BF_3 gas for counter filling. In contrast to the U.S., where a substantial demand existed, the initial European requirement was both small and sporadic. This fluctuating demand required a special approach to plant design in order to obtain an economic production unit. Development has taken the form of a multiplicity of basically independent units as it has been found that they give maximum flexibility from the point of view of output, range of enrichments and utilisation of raw materials.

The technical problems relating to the use of borontrifluoride etherate in chemical exchange/distillation plant arise almost entirely from two of its properties - its highly corrosive nature, particularly in the presence of small amounts of moisture and, its tendency to decompose at quite moderate temperatures. The following developments have been carried out with these limiting properties very much in mind.

Boiler designs, column packing, partial pressure control and extraction methods all affect the operating temperature in direct or indirect ways. Packing of high efficiency with low pressure drop has been developed, new

boilers have been designed and column head and extraction controls have been improved. The merits of cascade and single step units (enriching from natural abundance to 90% boron-10 in a single stage) are discussed and the latest design of single stage unit outlined. Our present plant consists of 8 such units producing 25 - 30 kg per year. Economic considerations also have an important bearing on design and such aspects as simplicity of operation and construction must be kept in mind. Equilibrium time is particularly important and the units described can be in full production within five weeks of commissioning. Thus a decision to increase production can be implemented relatively quickly.

As far back as 1949 some separation of carbon-13 was being carried out by the U.K. Atomic Energy Authority. The demand is still only of the order of grammes per week and, in the new plant, development has been directed towards economies both in the use of coolant (the main expense in manufacture) and on improving reliability. The commissioning of our new plant has doubled our production of carbon-13 and these developments are fully discussed.